The Global Operational Land Imager (GOLI)
Landsat 8 reflectance based active fire detection algorithm

Landsat Science Team Meeting
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Landsat 8 launch
Conventional Active fire detection (MODIS, AVHRR etc.)

based on differential increase of black body radiance
with temperature at ~4μm and ~11μm
Landsat 8 visible, NIR and SWIR reflective λ bands

Sample vegetation spectra
Modeled vegetation fire reflectance spectra

Flaming fire (1000K covering 0.5% of pixel)
Sample vegetation (covering 99.5% of pixel)

Flaming fire (1000K covering 100% of pixel)

Smoldering fire (450K covering 100% of pixel)

Sample vegetation (covering 100% of pixel)
Clouds (and snow at shorter $\lambda$) have a significant reflective contribution

Reflectance

B4 Red 0.65 $\mu$m
B5 NIR 0.86 $\mu$m
B6 SWIR 1.61 $\mu$m
B7 SWIR 2.2 $\mu$m

Sample vegetation (covering 100% of pixel)
Illustrative Landsat 8 fire examples
false color TOA reflectance
band 7 (2.2μm) / band 6 (1.61μm) / band 5 (0.86μm)

(300 x 300 30m pixel subsets)
Landsat 8 spectral scatterplots

39 million cloud-free/snow-free/unsaturated pixels extracted systematically across the USA for 3 Summer and Winter months

Visually identified active fire pixels: Southern Africa, Canada, U.S & Indonesia
Landsat 8 spectral scatterplots
Active fire detection tests: Murphy et al. 2016 RSE

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Unambiguous active fire detection tests: Schroeder et al. 2015 RSE

Visually identified active fire pixels: Southern Africa, Canada, U.S & Indonesia
Landsat 8 spectral scatterplots

Potential active fire detection tests: Schroeder et al. 2015 RSE

Visually identified active fire pixels: Southern Africa, Canada, U.S & Indonesia
**Modeled vegetation fire reflectance spectra**

Flaming fire (1000K covering 0.5% of pixel)
Sample vegetation (covering 99.5% of pixel)

Flaming fire (1000K covering 100% of pixel)
Smoldering fire (450K covering 100% of pixel)
Sample vegetation (covering 100% of pixel)
$B4 = 0.53 \times B7 + 0.047 \ (R^2 = 0.26)$

$Landsat 8$ spectral scatterplots

39 million cloud-free/snow-free/unsaturated pixels extracted systematically across the USA for 3 Summer and Winter months

$R^2 = 0.26$

$B6 = 1.1 \times B7 + 0.055 \ (R^2 = 0.91)$

$\rho_{0.65} = \frac{\rho_{2.2}^2}{2} \ (Kaufman \ et \ al. \ 1997; \ 2002)$
Landsat 8 spectral scatterplots

Unambiguous active fire detection tests: **GOLI**

Visually identified active fire pixels: Southern Africa, Canada, U.S & Indonesia
Landsat 8 spectral scatterplots

Potential active fire detection tests: **GOLI**

Visually identified active fire pixels: Southern Africa, Canada, U.S & Indonesia
Simulate TOA reflectance for different fire sizes and temperatures, and Landsat scene specific atmospheres (MODTRAN):

- \( \text{Toa } \rho_{\text{sim},\lambda} = \alpha_0 + \alpha_1 \cdot \text{Toa } L_{\text{sim},\lambda} \)
- \( \text{Toa } L_{\text{sim},\lambda} = \text{Toa } L_{\text{pix},\lambda} + \text{Toa } L_{\text{fire},\lambda} \)
- \( \text{Toa } L_{\text{fire},\lambda} = \text{Surf } L_{\text{fire},\lambda} \cdot \text{MODTRAN Atm},\lambda \)
- \( \text{Surf } L_{\text{fire},\lambda} = \text{FireArea } \cdot \text{Planck’s func.} (\lambda, \text{FireTemp}) \)
  - \( \text{FireArea} \) range 400k to 1200K
  - \( \text{FireTemp} \) range 1m^2 to 900m^2 (100% of 30m Pixel)

- > 100 million simulations for US, Canada, Southern Africa & Indonesia Landsat 8 non-fire pixels

- Run the 3 active fire detection algorithms using \( \text{Toa } \rho_{\text{sim},\lambda} \) and surrounding actual Landsat 8 30m \( \text{Toa } \rho_{\text{pix},\lambda} \) values

Omission errors- Theoretical TOA fire detection envelope

50% detection probability envelopes

GOLI algorithm
Schroeder et al. 2015 RSE
Murphy et al. 2016 RSE

Fire size [m^2]
Fire temperature [k]
Commission errors

- Typically occur over highly reflective buildings
  - High reflectance in bands used for active fire detection
  - High contrast with neighbors - Contextual detection
  - Not seen in coarse resolution MODIS 1km (Buildings << 1km)
  - Seen in VIIRS 375m
GOLI Commission error filter

- Identify pixel locations with high reflectance and in contrast to its neighbors
  - Composite $\text{MAX}(\rho_{2.2}/\rho_{0.86})$ from all Landsat 8 observations in the past 176 days

- Examine active fire detection locations using contextual tests in the composite
  - High contrast (pass contextual test) : Reject as commission error
China

false color TOA reflectance
band 7 (2.2 μm) / band 6 (1.61 μm) / band 5 (0.86 μm)

No fires

Path 119, Row 41
08/07/2014
75 x 75 30m pixels
China

GOLI active fire detection

Unambiguous active fire pixels

Potential fire pixels that passed contextual test

Clouds & Water

Path 119, Row 41
08/07/2014
75 x 75 30m pixels
China

GOLI active fire detection with commission error filter

Unambiguous active fire pixels

Potential fire pixels that passed contextual test

Commission error rejected by the filter

Clouds & Water

Path 119, Row 41
08/07/2014
75 x 75 30m pixels
Southern Africa

false color TOA reflectance

band 7 (2.2 μm) / band 6 (1.61 μm) / band 5 (0.86 μm)

Path 176, Row 072
08/06/2014
300 x 300 30m pixels
Southern Africa

**GOLI active fire detection with commission error filter**

Unambiguous active fire pixels

Potential fire pixels that passed contextual test

Commission error rejected by the filter

Clouds & Water

Path 176, Row 072
08/06/2014
300 x 300 30m pixels
Canada

false color TOA reflectance
band 7 (2.2\,\mu m) / band 6 (1.61\,\mu m) / band 5 (0.86\,\mu m)

Path 48, Row 17
07/20/2014
300 x 300 30m pixels
Canada

**GOLI active fire detection with commission error filter**

Unambiguous active fire pixels

Potential fire pixels that passed contextual test

Commission error rejected by the filter

Clouds & Water

Path 48, Row 17
07/20/2014
300 x 300 30m pixels
Summary

- A new globally applicable semi-empirical method for Landsat 8 active fire detection developed
- Has relatively fewer errors of omission and comparable errors of commission to past work
- Commission errors are largely over urban/industrial rooftops, not seen in MODIS but seen in VIIRS active fire detections
- We are actually funded to work on Landsat 8 & ESA Sentinel 2 burned area mapping; combination of Landsat 8 and Sentinel 2 reflective wavelength active fire detections provides
  - a unique opportunity to map active fires ~3-5 day temporal coverage
  - seeding burned area mapping algorithms for improved moderate resolution mapping
Landsat 8 spectral scatterplots
Unambiguous active fire detection tests: GOLI
Landsat 8 spectral scatterplots

Saturated Fire pixel identification
Schroeder et al. 2015 RSE

B6 (1.61 μm)

B7 (2.2 μm)

Saturated Fire pixel identification
Murphy et al. 2016 RSE

B5 (0.86 μm)

B6 (1.61 μm)
Commission errors

• Typically occur over reflective buildings
  • Bright in bands of interest (NIR- SWIR)
  • Contrast with neighbors

• Mitigation strategies: Schroeder et al. 2015 RSE
  • Examine 176 days of Landsat 8 reflectance before the active fire detection
    ▪ if there are active fire detections : Persistent source
    ▪ or, if average cloud & fire free $\rho_7 > 0.2$ : Bright source